Bayero Journal of Pure and Applied Sciences, 2(2): 207 - 217
Received: Augustl, 2009
Accepted: November, 2009

HYDROGEOLOGICAL MAP OF KABO SHEET 80 NW TOPOGRAPHICAL SHEET 1:50,000

I. Garba
Department of Geography, Kano University of Science and Technology, Wudil.
igdantsoho@yahoo.co.uk

ABSTRACT
A hydro geological mapping of the Federal Surveys of Nigeria, Kabo Sheet 80 NW, on scale 1:50,000 were made with areal coverage of 729Km^2 on the Crystalline Basement Complex, and the hydrogeoogical maps produced are maps of depth to the water table and maps of configuration peak of dry season and wet season, for 2 consecutive years. Hydrogeological cross-section, and hydraulic gradient was also determined as 0.015m. These configuration maps show depth of water and direction of groundwater flow and the constructed hydro geological maps of water tables show a correspondence between the water table contours and topographical contours; as well as revealed the effluent nature of the river system in the study area. Also hydrograph analysis of 2 (Km) gauging station at River Challawa was conducted for only 2 hydro years 1971/72, thus a total runoff average of 216,240,192m^3/a and mean base flow of 114,455m^3/a, and surface runoff mean of 159, 228,113m^3/a, also mean base flow coefficient of base 0.0182, and mean coefficient of surface runoff 0.062m were determined for the area.

Key words: Hydro geological maps, Configurations maps, Hydro years, Base flow, Coefficient of base flow and Hydraulic gradient.

INTRODUCTION

Kabo is one of the major towns in Kano state and lies on the Basement Complex rocks of northern Nigeria located southwest of the state. It is a densely settlement with water shortage problems even though with about four earthly dams in the area still people in the area experiences water shortage. Very little work was done on the study area especially on groundwater mapping with the exception of Isa, 1984; Hazel et al 1992; Edet et al ., 1994; Bala 2001 and Danbatta, 2000a and 2000b which gave an account of hydrogeology of the basement Crystalline complex. Many of other studies on the area were to the socio economic and environmental features of the study area. This research is aimed at assessing occurrence movement of surface and groundwater.

Study Area

Sheet 80 NW (1:50,000) is part of 80 Kabo 1:100,000 sheet in the topographical sheets of Nigeria located between latitudes 11^0 45′ N-12^0 00′ N and longitude 8^0 00′ E -8^0 15′ E. The sheet covers 729Km^2 comprising of Karaye, Kabo, Rimin-gado, some parts of Gwarzo and Tofa local governments areas of Kano state.

The area is accessible by road from Gwarzo to Kano city and also on the route from Makarfi –Kano. It is also accessible from Gwarzo- Kiru passing through Karaye town. Lastly, one can traverse the area from Karaye-Kabo through an untarred road.

Relief and Drainage

The area lies within the Hausa plain and highest elevation is in a village called Husure at eastern part of the area of about 564 metres above sea level, and a minimum elevation of 488 metres down south of the area and with an average height of 526 metres above sea level.

Drainage in the area is largely influenced by the relief; lowland areas have the Rivers and streams. River Challawa is the only big River with tributaries, Magaga, Takwami, Guzu- Guzu, Kutumbule, Iyaka, and the likes. The rivers are now mostly dammed and on river Challawa the popular Challawa Gorge dam was constructed in the year 1992. The area has a drainage density of 1.46Km/Km^2 as calculated by the author. The general pattern of drainage in the area is dendritic mostly running in the north south direction.

Climate and Vegetation

The area is part of the northern Nigeria within the tropical wet and dry climate, coded Aw according to Koppen's classification with an annual temperature of 25^0C (Stevenson screen temperature of Kano Airport) and mean minimum of 16-21^0C in the coolest month of December and January, and mean maximum of 30^0C in the months of April and May, (Olofin, 1987).

Rainfall is 800-1000mm per annum, on average (Schoeniech, 1998) is 900mm. This arises when southwest wind prevails over the area. Onset of rainy season begins May (early May) and ceases in October. Rainfall duration (wet season) has average of 153 days and dry season of 212 days, i.e. early October to late April characterized by hot days and cool nights. Also again on rainfall the distribution shows the characteristics of Northern sudan Savannah, pyramid, steeply ascending, also with mean annual rainfall from 1993- 2002 year of 115.07mm and a total of 1150.7mm. See Table 1.

The vegetation is of Sudan Savanna type with varieties of scattered trees over expanse grassland. Trees are characterized by broad canopies and hardly exceed height of 20 metres. Baobab is the peculiar tree taller than others. The vegetation has suffered and is still suffering as most of the people of the study area solely relies on fire wood as the source of domestic fuel, thereby, destroying the vegetation every day without planning or planting new ones to replace those cut down.

In the area government effort is seen on enhancing vegetational growth through forestation programmes as seen in Kabo and Karaye where Dogon yaro trees were planted.

Geology of the study area

The study area is underlain by the Precambrian-Crystalline rocks of which are:

The Migmatite gneiss

The Metasediments (consisting of quartzites and schists)

The Older granites.

(a) Granites

The area can be divided into 2 lithological units

a). Coarse grained porphyritic granites

b). Medium grained granites

The prophyritic granite are found mainly SW part of the area, extending to about 25KM down the area and the granites are coarse-grained with large or pink prismatic pheneocryst (Aroh, 1998). In some places occurs as whale backs trending NNE-SSW up to about 7 metre radius.

Metasediments

Schists outcrop mainly in the northern and central parts of the area and are exposed along streams and road cutting. They are mostly fine to medium grained with a general grayish color. (Akor 1998; Amade, 1998).

The qartzites are least in occurrences and are mostly found with schists and are whitish in colour with medium grained equiangular texture (Orhoevwri,1998). They can as well be observed along Dederi- Unguwar dabai village, occurring as elongated hills about 400-150 metres length and 130m width.

(b) Gneiss

Is most abundant of all the rock types present in the area as 50% of the area is gneissic rocks, in most places hosting shcists and quartzites,. It is almost foliated with alternating bands of light and dark minerals (Ogunmola, 1998). The banded gneiss are enriched with Mafic minerals and thin streaks of felsic bands, patches have been seen along River Kurma by the author.

(c) Superficial deposits

In rivers, streams and areas with deep weathering are thick superficial deposits, consisting of clay material, autochthonic of eluvia, diluvia or alluvial origin. On watersheds there are discontinuous layers of duricrust concretionary and vesicular, reddish brown color and, on the average, of 1m thick (Fig. 1).

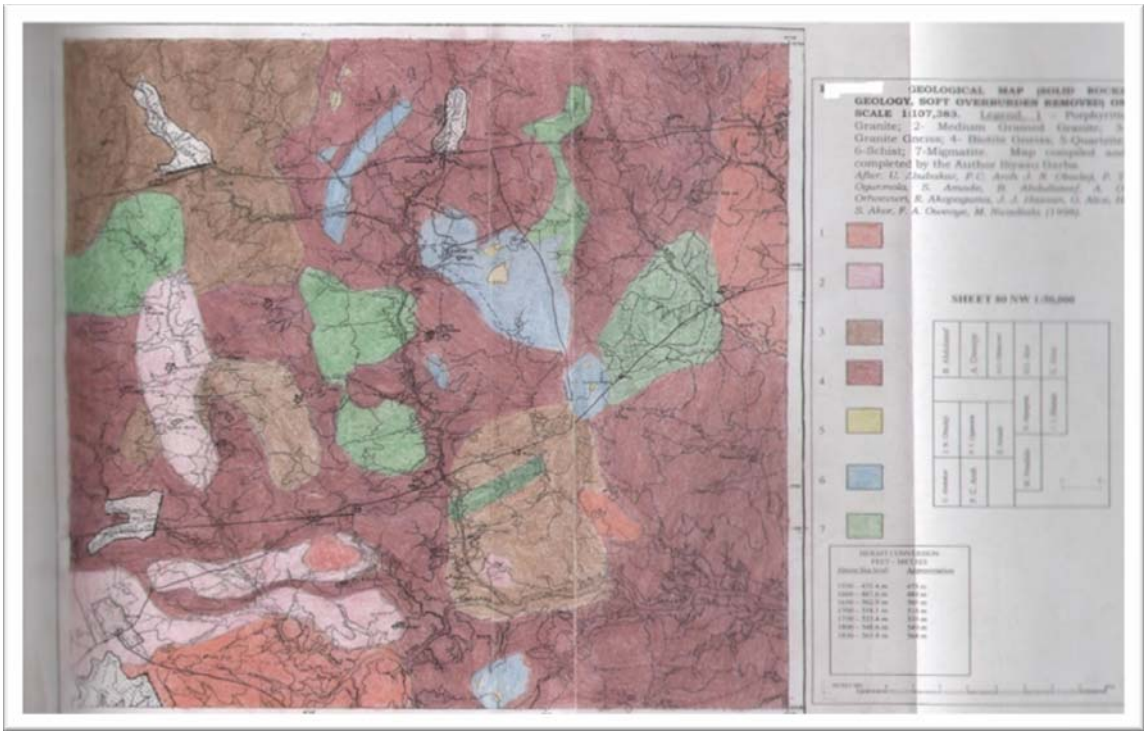

Figure 1: Geologic Map of Kabo and its environs (Solid geology).

MATERIALS AND METHODS

The methodologies followed are hydrogeological, i.e. measurement of depth of water in different hand-dug wells, completion and compilation of the geological map of the whole sheet 80 NW Kabo sheet (Study area).

The hydro geological mapping involved repeated measurements of depth of water levels during the dry and wet seasons 2001-2002 though some additional hand- dug wells were added in March 2002. Measurement was done with the aid of measuring tape at the end of which water levels maps were produced on a scale of 1:107,353. GPS (Global Positioning System) was used in taking records of locations (coordinates) and exact elevations of wells metres above sea level. The tape was also used to take the diameter of the wells. Past works on the area were also compiled and made use of both in reference and research. Field work was done in March 2001 to August 2002 data on water levels of 30-32 hand dug wells were taken during both dry and wet season. This was done simultaneously with identification of rocks, especially in area not covered previously.

RESULTS AND DISCUSSION

Hydrogeological Maps

Water table elevation map was drawn for the study area using Kriging mathematical interpolation method to establish the groundwater flow direction. Hydro geological maps were produced based on the data from field work and data obtained from KNARDA on (depth of water in boreholes drilled in 1986), all maps (Hydro geological maps) were constructed at a scale of 1:107,383 on the Kabo 80 NW topographical sheet. These maps are:

1. Two maps of Water Table Configuration and Direction of Flow at the Peak of Dry Season. One for peak in year 2001 and one for peak of dry season in year 2002.
2. One map of Water Table Configuration and Direction of Water Flow at Peak of Rainy Season in year 2001.
3. One map of Depth to the Water Table at the Peak of Dry Season.
4. Hydro geological Cross-Section.
5. Map of Solid Geology
6. Relief and Drainage Map.

Maps of Configuration of Water Table and Direction of Flow

Figure 2, 3 and 4 shows elevation of water levels at peak of both dry and rainy seasons. Figures 2 and 4 show a kind of correspondence with each other, likewise their directions of flows all starts from watersheds to the lowest environment in the study area or towards valleys. In all, these maps are drawn at interval of 15 meters, and from these maps it can be concluded that water table is controlled by topography (in soft overburden aquifer). The flow direction is in indicated by arrows that were drawn perpendicular to contour lines (equipotential lines, and all diverge from watershedes (high topographical areas) i.e. recharge areas, converges towards drainage channels/Rivers, as the discharge areas. From these maps can be concluded that main direction of groundwater movement is very similar throughout the 2 years of observations.

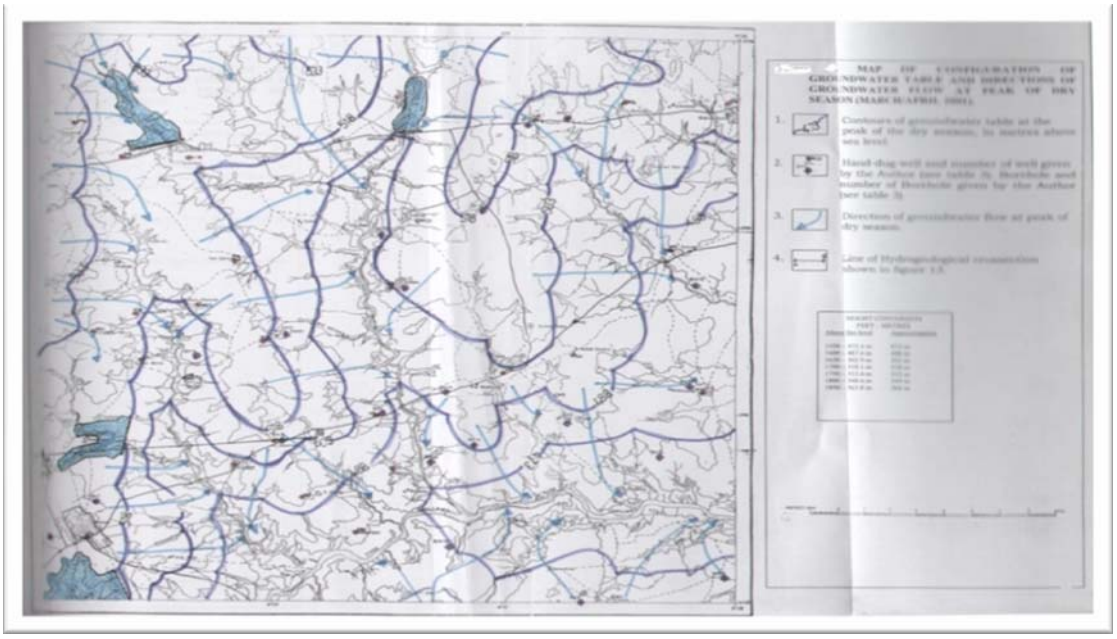

Figure 2: MAP SHOWING CONFIGURATIONS OF GROUNDWATER TABLE AND DIRECTIONS OF GROUNDWATER FLOW AT PEAK OF DRY SEASON (MARCH/APRIL, 2001) SCALE: 1:107,383

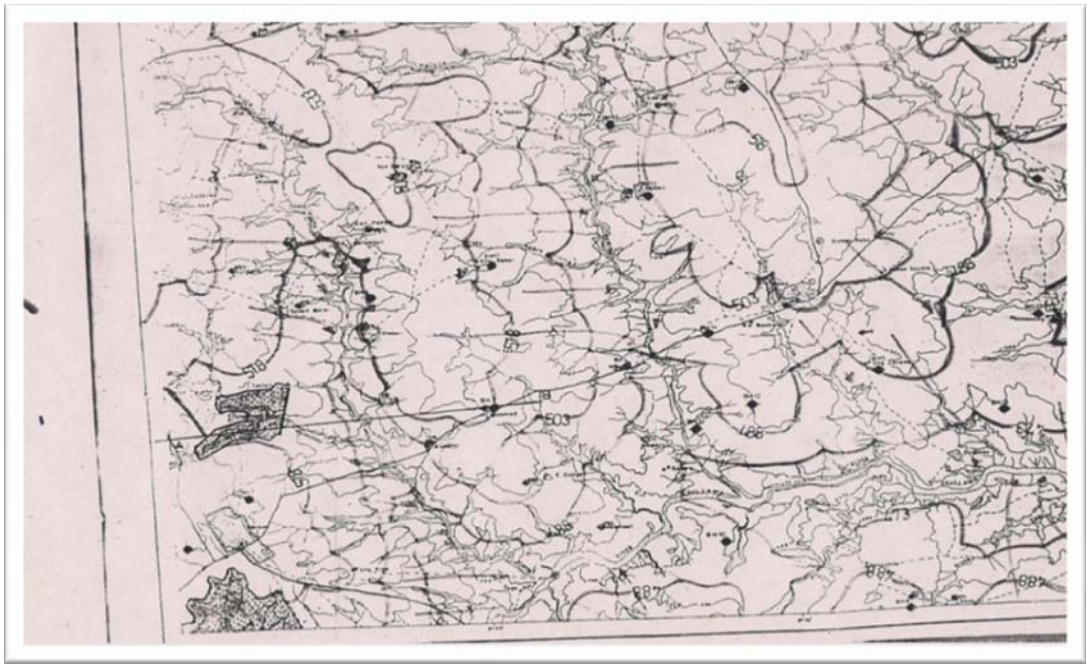

FIGURE 3: MAP OF CONFIGURATONS OF GROUNDWATER TABE AND DIRECTION OF FLOW AT PEAK OF RAINY SEASON (AUGUST, 2001). SCLAE 1: 107,383

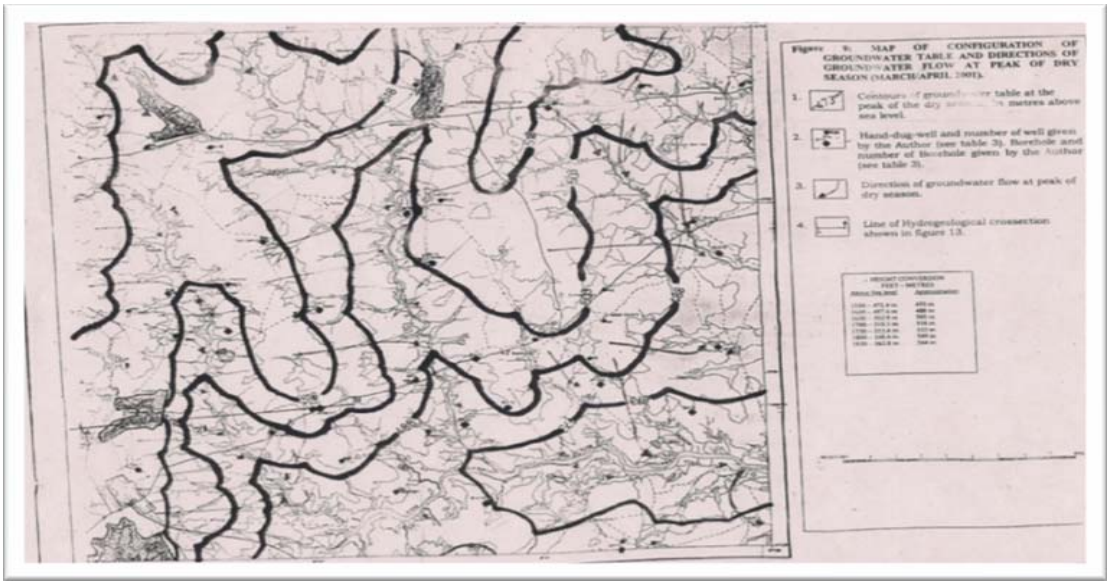

FIGURE 4 MAP OF CONFIGURATONS OF GROUNDWATER TABE AND DIRECTION OF FLOW AT PEAK OF DRY SEASON (MARCH, 2002).SCLAE 1: 107,383

Depth to Water Table Map

This is derived from the difference in elevation between the contour lines of ground surfaces and those of water table. This is of use in delimiting extent of areas on need of drainage. Contours from maps converted into metres from feet have intervals of 15m. This map was constructed by the Author by the use of the water levels measurements in boreholes and hand dug wells, in constructing depth to water table map for dry season year 2001. The method used is superimposition method, i.e. plotting depth to ground water level in wells as well as difference in elevation between topographical contour lines and water table on topographical map and draw lines to join points of equal values. Also differences in elevation between 2 contours were determined by superimposition of water table map on the topographical map Figure 5.

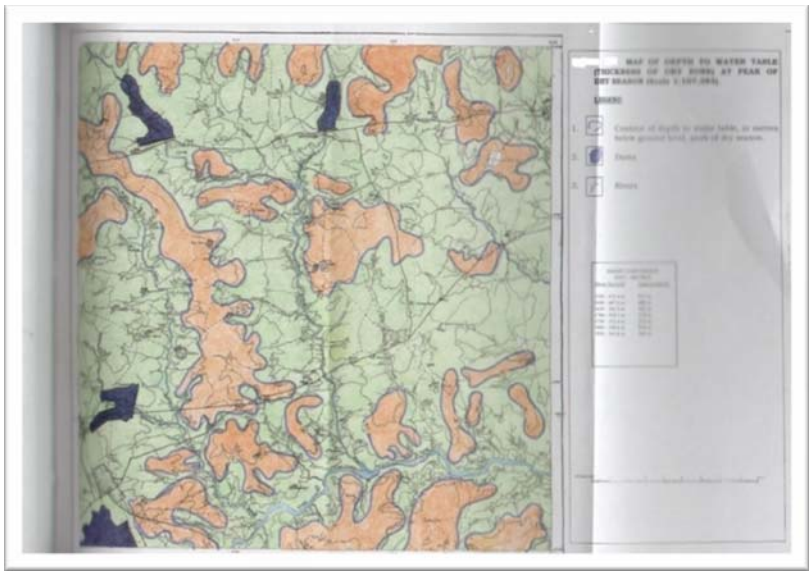

Figure 5 Depth to water table (Thickness of Dry Zone) at peak of DRY SEASON (scale 1: 107,783)

Hydro geological Cross Section

This was constructed from topographical map and maps of water table (fig.2 and 3). This shows that thickness of dry season for the 2001. This also confirms that dry zones is thickest at watersheds and that drainage is effluent since all the water table maps shows that all slopes towards River channels (areas of discharge).

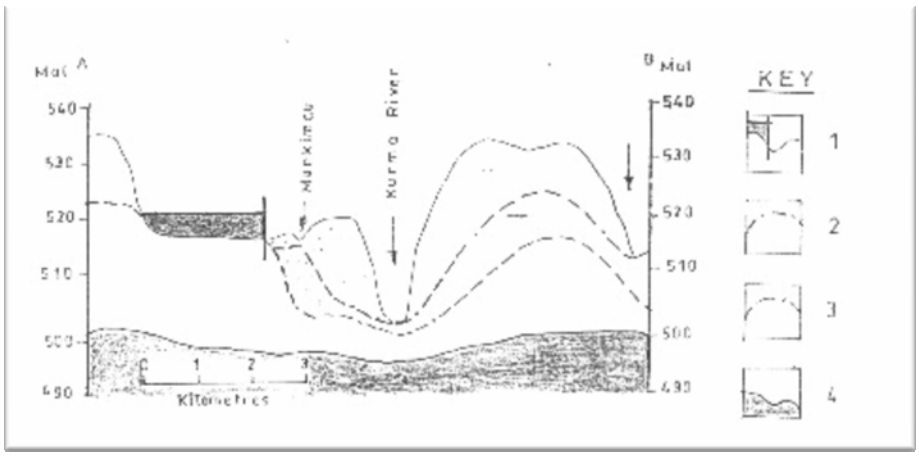

Figure 6. Hydrogeological cross section along line AB shown in figures 2 , and 4.
Explanation: 1- Surface water in Kusalla Dam, Munkimau and Kurma rivers, the last two are seasonal ones; 2-Ground water table at peak of rainy season (Aug. 2001);3-Ground water at peak of dry season (April 2001); 4- approximate boundary between solid crystalline rocks and soft overburden.

Calculation of Hydraulic Gradient

Hydraulic gradient was calculated using Darcys law, to know a specific discharge or volume/rate of flow through any cross sectional area perpendicular to the flow direction.

Q was calculated from the water table map drawn. Line X Y was drawn and thus was obtained. Using this procedure i.e. by calculating the hydraulic gradient along the flow lines of groundwater x y.

Already hydraulic gradient is defined as $I = \frac{H_A - H_B}{L}$

Where by H_A = Groundwater elevation of point X = 518m

H_B = Groundwater elevation of point Y = 503m

L = Distance between points x and y on map

This is measured from map to be 10cm from map.

From scale 1cm = 10,000cm
10cm = 100,000cm = 1000m

Therefore, $I = \frac{518m - 503m}{100cm} = \frac{15}{100} = 0.015$

$I = 0.015$

Note: I can be noted and calculated at any point on the contours.

Groundwater and surface water relationship

Source of water is rainfall, as not all of it goes into runoff part of it infiltrates to recharge aquifers (recharge of groundwater) from calculation in Challawa gauging station of 1971/72 and 1972/73 hydrograph has infiltration coefficient total of 0.062m and this does not correspond with Schoeneich,(1998) of 0.15m where depth of water is 0.9m. Actually why the difference is that data used by Scheoneich is on 1000km (medium catchment Areas) where as Challawa with 4589km^2 is larger than Schoeneich) (1998). Also data of Author average is scanty as only 2 hydrographs instead of 10years data. Also consideration of factors (basics), geology, relief time, onset rain and rain days all are considerations.

Table 4. Runoff and Coefficient for 2 years 1971/72 and 1972/73 Based on Hydrograph Analysis done by the Author.

Year	Vol. of Base flow m3/a	Vol. of Surface flow/runoff m3/a	Vol. of total runoff m3/a	Coeff. Of Base flow m3/a	Coeff. Of surface runoff m3/a	Coeff. Of total runoff m3/a
1971/72	63,251,021	215,688,946	278,939,967	0.018	0.062	0.080
1972/73	50,771,930	102,707,280	153,539,260	0.014	0.029	0.043
TOTAL	114,022,951	318,456,226	432,479,224	0.032	0.091	0.123
MEAN	570,114,755	159,228,113	216,239,613	0.016	0.045	0.062

There is also flow of water from the groundwater (water sheds area of recharge) towards streams and Rivers, which are termed as effluent. Groundwater also flows from fractures that are hidden. As discussed in surface water a spring exists but not in the study area, but in the Challawa Gorge dam which is a flows of water from the dam, people make use of it especially Karaye people, has a good taste as tested by Author.

Groundwater flow also supplement surface flow during dry season fig. 2, 3 and 4, so only River Challawa flows continuously (perennial) all other are either intermediate flow or seasonal, and others ephemerals, i.e. flows only when it rains, and are being fed by ground water recharge i.e. effluent.

Water resources of the area

Surface water occurrence

Surface water in the study area occurs in rivers and streams, with River Challawa the only perennial river in the study area. All others are either intermediate or ephemerals in nature. Surface water also exists in impounding reservoirs of four earth fill dams (colloquially called dams) constructed on these rivers. These are Challawa Gorge Dam constructed on River Challawa in 1992, Guzu-Guzu dam constructed on River Guzu-Guzu, Magaga dam on River Magaga and Kusalla dam on River Kurma at Karaye town.

A record on the hydrological data of the study area was kindly availed by the Author from WRECA very old of year 1972 and 1973. From Challawa station (gauging station).

Groundwater occurrence

Types of Groundwater occurrences revealed the hydrogeological maps compiled for this study revealed that groundwater is available in three media which are:

- Alluvial Aquifer, Soft Overburden Aquifer and Fractured Crystalline Aquifer

Alluvial Aquifers

These are found in Rivers e.g. River Kurma, River Takwami, and River Magaga, most are perennial containing water during the dry season. These aquifers are of great importance using for irrigation (small scale) by shadoof system called Jigo to water crops and vegetable like onion, tomatoes etc.

Soft Overburden Aquifer

Soft overburden consists of saprolite and regolith and is derived from the weathering product of the Basement rocks with chemically top of its clayey material of elluvial and alluvial origin which makes it heterogeneous.

Most of these are tapped by hand-dug wells and are seasonal bearing water in wet seasons and some at end of dry season, especially the ones that are seasonal loss their water flows to the alluvial aquifer . This aquifer covers most part of the study area (see maps of their locations). Hand-dug wells measurements show that minimum depth was 6m in Kabo and maximum of 32 in Butu-Butu (the only hand-dug well in Butu-Butu).

Fractured crystalline Aquifer

This is perennial, continuous throughout the year, tapped by borehole, this is extracted by method of geophysical survey technique, i.e. EMT (Electromagnetic Traverse) and VES i.e. (Vertical Electrical Sounding) and are termed as proven to be the best contribution (KNARDA, 1986). This aquifer is found in weathered zone, in Kano have EM from 15m-30m for vertical dipole, in Kano a typical profile of weathered zones are

- Fractures in poorly decomposed or weathering grades II^A and I
- Inter-granular permeability in moderately decomposed rocks or weathering grade III and II^A and

Zones of compositional change in highly weathered zones IV-III along veins, dykes, and gneiss, Migmatite or schist layers.

In the study area from results of KNARDA borehole drilled have an average depth of 46.0m and maximum depth of 73.5 in Gammo (Falgore), and minimum of 16.8m (Table 5).

CONCLUSION/RECOMMENDATIONS

The area is underlain by the rocks of the Basement Complex, completion and compilation of the map of solid Geology of the area was done to which produced a map of solid geology of the study area (sheet 80 NW Kabo 1:107,383). Hydrogeological maps of water tables were constructed and water table contours correspond with the topographical contours and reveals that River system is effluent, i.e. recharges are from water shed flowing to Rivers. (Figures 2,3 and 4). The results also reveal the direction of flow, the depth to water table and the extent of areas in need of drainage. The hydraulic gradient was computed as 0.015m.

Three types of aquifers wee determined namely, soft overburden, with minimum depth of 6m and maximum of 32m, and fractured crystalline aquifer with depth maximum and minimum of 73.4 and 16.8m were determined with an average of 46.0m. The third is alluvial, which exist in Rivers with minimum depth of 3m.It is recommended that study of these types will give in depth knowledge of water studies and exploration.

REFERENCES

Amade, S. E. (1998): Geology of 1:50,000, Kabo NW sheet. Unpub. B. Sc project Department of Geology, ABU Zaria.

Akor, H.S. (1998): The Geology of part of Kabo Sheet 80 NW. Unpublished B.sc Project, Department of Geology, ABU, Zaria.

Aroh, P.C. (1998): Geology of 1:50,000 Kabo NW Sheet, Unpublished B.sc Project Department of Geology, ABU Zaria.

Bala, E.A. (2001): A symbological interpretation of fractures for the assessment of groundwater potential of Wudil and environs, Central Northern Nigeria. Water resources, 12, 27-31

Danbatta, U.A. (2000a): An overview of the Hydrogeology of Nigeria. In: A training manual on Improved National Access to Water Supply and Sanitation program (INAWSS), Workshop on capacity building and sustainability (Phase I). Organized by Federal Ministry of Water Resources and Water-Pure, Kaduna 3-12.

Danbatta, U.A. (2000b): Hydrogeological Studies of groundwater occurrence in Kano state, Nigeria. In: A training manual on Improved National Access to Water Supply and Sanitation program (INAWSS), Workshop on capacity building and sustainability (Phase I). Organized by Federal Ministry of Water Resources and Water-Pure, Kaduna 13-18.

Edet, A.E Teme, C.S. Okereke,S Esu E.O. (1994): Lineament Analysis for groundwater exploration in Precambrian Oban massif and Obudu Platue, SE Nigeria. Journal of Mining Geol. 30 (1) 87-95

Hazell, J.T.R, Cratchely, C.R, Jones, C.R.C (1992): The Hydrogeology of Crystalline Aquifers in northern Nigeria and Geophysical techniques used in their exploration. In: Wright, E.P, Burges, BW. G (eds) Hydrogeology of Crystalline Basement Aquifers in Africa. Geological society Special Publication. 66. 155-182.

KNARDA, (1986): Year book, records of work (1983-86).

Ogunmola, P.T. (1998): Geology of part of 1:50,000 80 Kabo NW sheet. Unpub. B.sc. Project, Department of Geology, A.B.U, Zaria

Olofin, E.A. (1987): Some Aspect of Physical Geography of Kano State Region and its Related Human Responses, Unpublished Departmental Lecture Note. Geog 2112 Series, Note no. 1. Department of Geography, B.U.K. Kano.

Orheovwri, A.O. (1998): The Geology of part of Sheet 80 NW, Kano State. Unpub. B.sc Project, Department of Geology, A.B.U. Zaria.

Schoeneich, K. (1998): Geol. 400 Hydrogeology Lecture Notes Unpublished, Department of Geology, ABU Zaria

Table 1: Well Locations, Depth, Both Dr and Wet Season March And April, 2001 And August 2001 Respectively (coordinates were measured with GPS, and depth with measuring tapes) while elevation of well was read from topographical map

No.	Locations	Coordinates	Elevation of well (masl)	Date of measurement	Depth of water table(mbgl))	Elevation of water table	Date of measurement	Depth of water tale (mbgl	Elevation of water table (masl)	Well description
1	Karaye	11 47 11N 8 00 58E	531	11/04/01	28	503	30/8/01	2.30	528.7	District head palace
2.	Yammedi	11 49 20N 8 04 56E	534	"	27	507	"	2.2	509	Primary school
3.	Kangarawa	11 49 40N 8 04 34 E	535	"	17	518	"	1.5	520	Before the village
4.	Dederi	11 50 49N 8 03 26E	523	"			"	7.2		
5.	Kafi	11 49 47N 8 06 38E	519	"	8	511	"	6	513	
6.	Kabo	11 51 22N 8 10 17E	510	"	6	504	"	1.8	508.2	In Hospital
7.	Kibalbal	11 50 13N 8 11 56E	505	"	18	495	"	3.6	501.4	Local Fulani's well
8.	Malam gajere	11 51 39N 8 11 45E	508	"	18	485	"	15.2	492.8	In a farm before prim.sch.
W9	Massanawa	11 51 36N 8 14 44E	489	"	20	469	"	16.4	472	Near big tree in town
W10	B/Shira	11 52 48N 8 11 49E	514	"	20	494	"	17.5	496.5	In farm
W 11	Wari	11 53 37N 8 12 30E	514	"	22	463	"	18	479	In farm used by Fulani's
W12	Agalawa	11 53 51N 08 11 08E	523	"	18	505	"	16	507	In the village
W13	Durum	11 51 19N 08 13 47E	502	"	29	473	"	24	478	Concrete lined in the village
W14	Shadau	11 52 56N 08 12 28E	515	"	17	499	"	12	502	
W15	gammo	11 53 21N 08 08 13E	520	"	26	494	"	23.5	497	Close to the overhead tank
W16	Godiya	11 55 03N 8 11 56E	521	"	13	508	"	10	511	Close to the pond
W17	Rimin -gado	11 58 02N 8 12 04E	520	11/04/01	6	514	30/08/01	2.5	518	Concrete lined along the road to Kano
W18	Butu-Butu	11 58 11N 8 12 41E	532	"	32	500	"	29	503	Inside an unused house
W19	Indabo	11 57 41N 8 10 57E	519	"	15	504	"	11	508	Near the Road
W20	Sari garin	11 58 04N 8 07 34E	525	"	12	513	"	10	515	in the market
W21	Katsinawa	11 57 12N 8 07 46E	519	"	10	509	"	2.5	516.5	
W22	Garo	11 56 56N 8 06 11E	527	"	11	526	"	2	525	
W23	Gude	11 56 50N 8 02 12E	531	"	22	509	"	21	510	In the mosque

Table 1 continue

W24	Husure	11 57 19N 8 00 30E	565	"	21	543	"	20.5		In the mosque
W25	Dam amali	11 56 50N 8 01 50	540	"	20	520	"	6.6		Concrete lined
W26	Sabon birni	11 51 12N 8 02 11E	532	"	7	525	"	5.2	527	
W27	Makada	11 53 53N 8 01 40E	534	"	9	525	"	5	527	
W28	Dadarau	11 53 42N 8 00 20E	551	"	12	537	"	8	543	
W29		11 45 52N 8 11 02E	492	12/04/01	18	475	31/08/01	12	481	
W30	Zuwo	11 45 11N 8 11 31E	487	"	15	472		9	478	

Source: fieldwork 2001.

Table 2: Well Locations, Depth, Both Dry and Wet Season April 2002 Respectively Coordinates were measured with PS and depth with measuring tapes) wile elevation of well was read from topographical map

No	Location	Coordinates	Elevation of well	Date of measurement	Depth of water table (mbgl)	Elevation of water table	Depth of water table(mbgl)	Elevation of water table (masl)	Remarks
1	Zuwo	11 45 50N 8 12 34E	486	17/4/02	16.6	469.4	16.4	1.2	Concrete lined
2.	danashina	11 45 50N 8 10 50E	496	"	21.9	471.1	12.4	0.7	
3.	Karaye	11 46 44N 8 01 04E	531	"	11.2	519.8	3.9	1.2	
4.	Audawa	11 48 41N 8 04 13E	516	"	13.65	502.35	12.33	1.27	
5.	Yammedi	11 49 16N 8 05 13E	534	"	25.35	508.65	25.50	1.25	
6.	Dederi	11 50 55N 8 03 15E	523	"	12.03	510.97	11.8	1.20	
7.	Kafi	11 49 56N 8 07 53E	519	"	7.28	511.72	6.9	1.72	
8.	Kabo	11 51 05N 8 10 04E	508	"	4.92	505.08	3.45	0.85	
9.	Kibalbal	11 50 31N 8 11 17E	505	"	6.8	498.2	6.35	Not measured	
10	Massanawa	11 51 39N 8 14 27E	489	"	20.8	468.2	23.9		
11.	Mallam Gajere	11 51 39N 8 11 39E	508	"	9.11	500.89	8.2	"	Late rite walled
12.	Durum	11 54 23N 8 13 42E	503	"	32.2	470.8	26.56	1.6	"
13.	Wari	11 52 31N 8 11 42E	514	"	19.95	494.05	20.02	Not measured	"
14.	Butu butu	11 58 23N 8 12 43E	532	"	28.26	501.7	25.9	"	"
15.	Rimin gado	11 58 23N 8 14 55E	520	"	8.97	511.03	8.72	1.20	Concrete lined

Table 2 continue

16.	Indabo	11 57 55N 8 11 16E	519	"	13.97	505.03	13.64	1.85	"
17.	Garo	11 57 15N 8 06 21E	527	11/04/02	11.6	515.4	6.5	1.27	"
18.	Gude	11 56 47N 8 03 18E	540	"	22.93	507.07	20.30	1.2	Laterite waled
19.	Zangon Amali	11 01 45N 8 01 53E	540	"	13.37	526.63	8.5	1.2	"
20.	Matankari	11 46 51 8 06 54E	495	20/04/02	7.10	487.9	7.0	Not measured	Walled with drum
21.	Kafin dabga	11 47 51N 8 05 41E	519	"	10	509			
22.	kawara	11 48 44N 8 07 00E	503	"	12.50	490.5			Laterite walled
23.	Unguwar dabai	11 51 58N 8 07 52E	534	"	23.60	510.4		1.3	Concrete lined
24.	Yan Guruza	11 54 06N 8 04 16E	535	"	20.90	514.1		1.35	"
25.	Dan madadi	1 52 55N 8 03 30E	533	"	10	520	12.2	1.30	
26.	Bagwayawa	11 52 55N 8 02 13E	534	"	10	524	12.2	1.32	"
27.	Jundumo	11 52 11N 8 02 32E	547	"	6.9	540.1	6.10	1.10	
28.	Sabon Birni	11 51 26N 8 02 32E	532	"	6.45	5255	6.0	1.25	
29.	Gammo	11 53 25N 8 07 40E	519	21/04/02	10	509		1.20	
30.	Godiya	11 55 09N 8 08 24E	521	"	12.35	508.65			

Source: field work 2002.

Table 3: Borehole data kindly available From KNARDA(Kano State) Compiled by Author, labels GR-Granite, MET Metamorphic, PBKGR-Porphiritic Black Granite, CPGR-Coarse Porphiritic Granite, By Converting EC to Mineralization, Using Conversion factor 0.7

	Location	Long/lat	Date of measurement	Depth(M	Elevation of Borehole(masl)	SWL(M)	Elevation of Water (masl)	Rock type	Water quality PH	EC
BH1	Jamaa Kosa	11 46 40N 8 01 12E		16.8	533	10.30	516.2	MET	6.95	140
BH2	Yammedi	11 49 18N 8 05 16E	3/03/84	53.2	529	17.40	475.8	MET	7.00	180
BH3	Kafin Dabga	11 48 45N 8 08 40E	3/04/84	40.6	508	9.0	467.4	CPGR	6.90	105
BH4	Kafin Dabga	11 50 00N 8 07 30E	7/12 85	61.5		12.0		GR	6.70	130
BH5	Kurungu	11 49 45N 8 11 30E	8/01/8640	40	505	13.70	465	GR	6.6	210
BH6	Walawa	11 51 30N 8 03 30E	3/05/87	47.0	510	14.35	463	MET	6.85	190
BH7	Madobawa	11 4720N 8 01 20E	2/01/84	52.0	533	14.60	481	MET	0.00	0
BH8	Zuwo (Danashina)	11 45 20N 8 14 55E	7/02/84	29.4	491	26.40	446.7	MET	7.05	220
BH 9	Galadimawa	11 45 20N 8 14 5E	7/02/84	42.3	489	26.40	446.7	MET	6.80	280
BH10	Kadangaru	11 46 32N 8 09 00E	11/12/85	59.0	490	21.20	431	MET	6.80	280
BH11	Hawaden Galadima	11 05 48N 8 14 13E	2/2/84	59.0	490	21.20	431			
BH 12	Kanwa tofa	11 9 10N 8 09 30E	10/02/84	39.0	504	18.93	475	GR	6.85	100
BH13	Danmaliki	11 53 22N 8 08 06E	28/10/87	58.0	520	23.00	462	MET	6.00	0
BH14	Baskore	11 50 36N 8 08 56E	9/02/84	52.3	503	16.85	450.7	MET	6.64	650
BH15	Ungwar Turaki	11 48 55N 8 13 36E	2/01/86	71.0	490	20.00	419	MET	6.60	170
BH16	Godiya	11 54 23N 8 07 30E	03/01/86	40.00	518	26.70	478	MET	6.10	290
BH18	Gammo (falgore)	11 52 56N 8 05 18E	"	73.5	522	21.40	448.5	MET	7.40	260
BH19	Balam	11 56 40N 8 09 40E		55,5	531	19.69	475.5	PBKGR	7.20	274
BH20	Hawaden bayo	11 53 30N 8 14 20E	4/02/89	65.0	489	0.00	424		00	00
BH21	Marken Gwasamai	11 57 40N 8 10 40E	02/02/89	52.5	520	21.85	467.5	MET	7.90	472
BH22	Kasadawa	11 57 50N 8 11 30E	09/06/89	46.5	523	0.00	476.5	MET	0.00	0